BIOLOGY AND SEASONAL INCIDENCE OF BRINJAL SHOOT AND FRUIT BORER, *Leucinodes orbonalis* Guenee

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
in
ENTOMOLOGY
(Minor Subject: Plant Pathology)

By

Poonam Singla
(L-2010-A-39-M)

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CERTIFICATE I

This is to certify that the thesis/dissertation entitled, **"BIOLOGY AND SEASONAL INCIDENCE OF BRINJAL SHOOT AND FRUIT BORER, *Leucinodes orbonalis* Guenee"** submitted for the degree of **Master of Science**, in the subject of **Entomology** (Minor subject: **Plant Pathology**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Ms Poonam Singla (L-2010-A-39-M)** under my supervision and that no part of this thesis/dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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(Dr Manmeet Brar Bhullar)
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CERTIFICATE II

This is to certify that the thesis entitled, **"BIOLOGY AND SEASONAL INCIDENCE OF BRINJAL SHOOT AND FRUIT BORER, *Leucinodes orbonalis* Guenee"** submitted by **Ms Poonam Singla (L-2010-A-39-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science**, in the subject of **Entomology** (Minor subject: **Plant Pathology**) has been approved by the Student's Advisory Committee along with Head of the Department after an oral examination on the same.

(Dr Balwinder Singh)
Head of the Department

(Dr Manmeet Brar Bhullar)
Major Advisor

(Dr Gursharan Singh)
Dean Postgraduate Studies

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ABSTRACT

The biology and seasonal incidence of brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* was studied during 2011-12 on brinjal variety Punjab Sada Bahar at the Entomological Research Farm and Acarology Laboratory, PAU, Ludhiana. The different parameters of biology viz. incubation period, larval period, pupal period, oviposition, fecundity, adult longevity and sex ratio were studied during different seasons i.e. June, August and October. Observations on the seasonal incidence of BSFB on shoots and fruits were also recorded. The results revealed that there was significant difference in duration of all the biological parameters during three different seasons and minimum duration of incubation period (3.19 days), larval period (11.31 days), pupal period (7.11 days) was observed during August when mean temperature and relative humidity was 29.65ºC and 79.25 per cent respectively. The total life span was observed to be shortest during August followed by June and October. Studies on seasonal incidence revealed peak infestation on shoots during 31st Standard week(SW) and fruits during 32nd SW. Shoot incidence was also reported from 44th to 52nd SW and 14th to 18th SW but the intensity of damage was low. Similarly, fruit damage was also observed from 44th to 52nd SW but intensity was low. Further, this pest was reported to feed on crops like *Lycopersicon esculentum* (Tomato) and *Solanum tuberosum* (Potato) and weeds viz. *Solanum nigrum* (‘Makoh’) and *Physalis minima* (‘Bhumbla’) all belonging to family Solanaceae.

Keywords: *Leucinodes orbonalis*, biology, seasonal incidence, biometric analysis

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ਸਾਰ

ਮੌਜੂਦਾ ਖੋਜ ਦੌਰਾਨ ਪੰਜਾਬ ਖੇਤੀਬਾੜੀ ਲੁਧਿਆਣਾ ਦੇ ਐਂਟੋਮੋਲੋਜੀਕਲ ਤਜ਼ਰਬਾ ਫਾਰਮ ਅਤੇ ਅਕੈਰੋਲੋਜੀ ਪ੍ਰਯੋਗਸ਼ਾਲਾ ਵਿਖੇ ਸੰਨ 2011-12 ਦੌਰਾਨ ਬੈਂਗਣ ਦੀ ਕਿਸਮ ਪੰਜਾਬ ਸਦਾ ਬਹਾਰ ਵਿੱਚ ਬੈਂਗਣ ਦੀ ਟਾਹਣੀ ਅਤੇ ਫ਼ਲ ਦੇ ਕੀੜੇ (ਬੀ.ਐਸ.ਐਫ.ਬੀ.) ਦੇ ਜੀਵਨ ਚੱਕਰ ਅਤੇ ਮੌਸਮੀ ਆਪਤਨ ਦਾ ਅਧਿਐਨ ਕੀਤਾ ਗਿਆ। ਖੋਜ ਦੌਰਾਨ ਵੱਖੋ-ਵੱਖ ਮਹੀਨਿਆਂ (ਜੂਨ, ਅਗਸਤ ਅਤੇ ਅਕਤੂਬਰ) ਦੌਰਾਨ ਵੱਖੋ-ਵੱਖਰੇ ਜੈਵਿਕ ਮਾਪਦੰਡਾਂ ਜਿਵੇਂ ਕਿ ਇੰਨਕੁਬੇਸ਼ਨ ਮਿਆਦ, ਆਂਡੇ ਵਿੱਚੋਂ ਬੱਚੇ ਨਿਕਲਣ ਦੀ ਮਿਆਦ, ਪਿਉਪਲ ਮਿਆਦ, ਓਵੀਪੋਜੀਸ਼ਨ, ਉਪਜਾਉਪਨ, ਕੀੜੇ ਦੀ ਉਮਰ ਅਤੇ ਲਿੰਗ ਅਨੁਪਾਤ ਦਾ ਅਧਿਐਨ ਕੀਤਾ ਗਿਆ। ਟਾਹਣੀਆਂ ਅਤੇ ਫ਼ਲ ਉਪਰ ਬੀ.ਐਸ.ਐਫ.ਬੀ. ਦੇ ਮੌਸਮੀ ਆਪਤਨ ਸਬੰਧੀ ਆਂਕੜੇ ਇੱਕਠੇ ਕੀਤੇ ਗਏ। ਨਤੀਜਿਆਂ ਤੋਂ ਇਹ ਤੱਥ ਸਾਹਮਣੇ ਆਏ ਕਿ ਸਾਰੇ ਹੀ ਸਾਰੇ ਮਹੀਨਿਆਂ ਦੌਰਾਨ ਸਾਰੇ ਹੀ ਜੈਵਿਕ ਮਾਪਦੰਡਾਂ ਵਿੱਚ ਅਰਥਪੂਰਨ ਵਿਭਿੰਨਤਾ ਸੀ ਅਤੇ ਅਗਸਤ ਮਹੀਨੇ ਦੌਰਾਨ ਜਦੋਂ ਔਸਤ ਤਾਪਮਾਨ ਅਤੇ ਨਮੀ ਕ੍ਰਮਵਾਰ 29.65^{o} ਸੈਲਸੀਅਸ ਅਤੇ 79.25% ਸੀ, ਇੰਨਕੁਬੇਸ਼ਨ ਪੀਰੀਅਡ ਦੀ ਮਿਆਦ (3.19 ਦਿਨ), ਲਾਰਵਲ ਮਿਆਦ (11.31 ਦਿਨ), ਪੀਉਪਲ ਮਿਆਦ (7.11 ਦਿਨ) ਸਭ ਤੋਂ ਘੱਟ ਦਰਜ ਕੀਤੀ ਗਈ। ਅਗਸਤ ਮਹੀਨੇ ਦੌਰਾਨ ਕੀੜੇ ਦਾ ਕੁੱਲ ਜੀਵਨ ਕਾਲ ਸਭ ਤੋਂ ਛੋਟਾ ਸੀ ਅਤੇ ਇਸ ਮਗਰੋਂ ਜੂਨ ਅਤੇ ਅਕਤੂਬਰ ਵਿੱਚ ਕੀੜੇ ਦਾ ਜੀਵਨ ਕਾਲ ਛੋਟਾ ਪਾਇਆ ਗਿਆ। ਮੌਸਮੀ ਆਪਤਨ ਤੇ ਕੀਤੇ ਅਧਿਐਨ ਤੋਂ ਪਤਾ ਚੱਲਿਆ ਕਿ ਟਾਹਣੀਆਂ ਉਪਰ ਕੀੜੇ ਦਾ ਸਭ ਤੋਂ ਵਧੇਰੇ ਪ੍ਰਕੋਪ 31ਵੇਂ ਸਟੈਂਡਰਡ ਹਫਤੇ ਅਤੇ ਫ਼ਲਾਂ ਉਪਰ ਇਹ ਪ੍ਰਕੋਸ ਸਭ ਤੋਂ ਵਧੇਰੇ 32ਵੇਂ ਹਫਤੇ ਵੇਖਿਆ ਗਿਆ। ਫ਼ਸਲ ਵਿੱਚ ਟਿਹਣੀ ਦਾ ਨੁਕਸਾਨ 44ਵੇਂ ਤੋਂ 52ਵੇਂ ਅਤੇ 14ਵੇਂ ਤੋਂ 18ਵੇਂ ਹਫਤੇ ਦੌਰਾਨ ਵੇਖਣ ਨੂੰ ਮਿਲਿਆ ਪਰ ਇਸ ਨੁਕਸਾਨ ਦੀ ਤੀਬਰਤਾ ਬਹੁਤ ਘੱਟ ਸੀ। ਇਸੇ ਤਰ੍ਹਾਂ ਫ਼ਲਾਂ ਦਾ ਨੁਕਸਾਨ 44ਵੇਂ ਤੋਂ 52ਵੇਂ ਹਫਤੇ ਦੌਰਾਨ ਹੋਇਆ ਅਤੇ ਇਸਦੀ ਤੀਬਰਤਾ ਵੀ ਬਹੁਤ ਘੱਟ ਸੀ। ਇਹ ਕੀੜਾ ਸੋਲੇਨੇਸੀ ਪ੍ਰਜਾਤੀ ਨਾਲ ਸਬੰਧਤ *ਲਾਈਕੋਪਰਸੀਕੋਨ ਐਸਕੁਲੇਂਟਮ* (ਟਮਾਟਰ) ਤੇ *ਸੋਲੇਨਮ ਟੁਬਰੋਸਮ* (ਆਲੂ) ਦੀ ਫ਼ਸਲ ਅਤੇ ਨਦੀਨਾਂ ਜਿਵੇਂ ਕਿ *ਸੋਲੇਨਮ ਨਾਈਗ੍ਰਮ* ('ਮਕੋਹ') ਅਤੇ *ਫਾਈਸੇਲਿਸ ਮੀਨੀਮਾ* ('ਬੂੰਬਲਾ') ਉਪਰ ਵੀ ਪਾਇਆ ਜਾਂਦਾ ਹੈ।

ਮੁੱਖ ਸ਼ਬਦ: *ਲੁਸੀਨੋਡਸ ਓਰਬੋਨੇਲਿਸ,* ਜੀਵ ਵਿਗਿਆਨ, ਮੌਸਮੀ ਆਪਤਨ, ਬਾਇਓਮੈਟ੍ਰਿਕ ਮੁਲਾਂਕਣ

ਪ੍ਰਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ

ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ

CONTENTS

CHAPTER – I

INTRODUCTION

Vegetables are an important source of vitamins, minerals, and plant proteins in human diet throughout the world. Vegetable cultivation is one of the most dynamic and major branches of agriculture, and is most important from the point of view of economic value. Vegetables are rapidly becoming an important source of income for the rural population. At the same time, vegetable cultivation is becoming more costly due to the increasing use of purchased inputs such as pesticides and fertilizers to sustain production levels. These inputs are also a cause for concern due to their deleterious effect on human health and the environment.

Brinjal (*Solanum melongena* L.) belonging to family Solanaceae is a popular and economically important vegetable crop among small-scale farmers and low-income consumers of South Asia and this region accounts for nearly 60 per cent and 53 per cent of world's area and production, respectively. It shows the secondary diversity in China and South East Asia (Singhal 2003).

In India, it occupies an area of 704.96 thousand hectares with an annual production of 12994.77 thousand metric tonnes (Anonymous 2013). It is a major vegetable crop of the plains (Nath *et al* 1987). The major brinjal growing states in India are Andhra Pradesh, Karnataka, West Bengal, Tamil Nadu, Maharashtra, Orissa, Uttar Pradesh, Bihar and Rajasthan.

In Punjab, the crop is grown over an area of 3.38 thousand hectares with an annual production of 71.76 thousand metric tonnes (Anonymous 2013). Brinjal is primarily consumed as cooked vegetable and its dried shoots are used as fuel in rural areas. It is low in calories and fats and is a good source of minerals and vitamins. It is also rich in total water soluble sugars, free reducing sugars and amide proteins.

Brinjal is subjected to attack by number of insect and mite pests right from nursery stage till harvesting (Regupathy *et al* 1997). Among the insect pests infesting brinjal, the major ones are shoot and fruit borer, *Leucinodes orbonalis* Guenee; whitefly, *Bemisia tabaci* (Gennadius); leaf hopper, *Amarasca biguttula biguttula* (Ishida); Hadda beetle, *Henosepilachna vigintioctopunctata* (Fabricius) and non insect pest like red spider mites, *Tetranychus macfarlanei* (Baker and Pritchard) and *Tetranychus urticae* Koch. Out of these, *L. orbonalis* is the key pest throughout Asia (Purohit and Khatri 1973, Kuppuswamy and Balasubramanian 1980, Allam *et al* 1982, Patial and Mehta 2008). This pest is reported from

all brinjal growing areas of the world including Germany, Burma, USA, Srilanka and India. In India this pest has a countrywide distribution and has been categorized as the most destructive and serious pest causing huge losses in brinjal (Patil 1990). It is known to damage shoot and fruit of brinjal in all stages of its growth. Brinjal shoot and fruit borer (BSFB) is considered a limiting factor in brinjal cultivation and causes losses as high as 70 to 92 per cent (Krishnaiah and Vijay 1975, Nair 1975). It may cause 100 per cent damage if no control measures are applied (Rahman 2007). This pest is very active and cause significant damage during the rainy and summer season (Ali *et al* 1980, Kalloo 1988, Jhala *et al* 2007).

In early stage of the crop growth, the larva bores into the shoots resulting in drooping, withering and drying of the affected shoots. During the reproductive stage, tiny larva bores into the flower buds and fruits, the bored holes are invariably plugged with excreta. The infested fruits become unfit for human consumption due to loss of quality and lose their market value. It has also been reported that there could be reduction in vitamin C content in the infested fruits. Insecticidal control is one of the common means against the fruit borer but many of the insecticides applied do not provide satisfactory control of this pest. In brinjal, use of chemical insecticides will leave considerable toxic residues on the fruits. Beside this, sole dependence on insecticides for the control of this pest has led to development of insecticidal resistance (Natekar *et al* 1987). BSFB has a very wide host range. Besides brinjal, it attacks other solanaceous plants such as *Solanum tuberosum* L. (Potato), *S. aculeatissimum* Jacq. (Indian nightshade), *S. indicum* L. (Black nightshade), *S. myriacanthum* Dunal (*kota bengena*), *S. torvum* Swartz (Turkey berry), *Lycopersicon esculentum* Mill. (Tomato), *Capsicum annum* L. (Bell pepper) and some weeds (Anonymous 2011).

The research and development activities to combat BSFB have largely been confined to screening pesticides to select the most effective chemical and determining the frequency of their use. At one time, researchers developed pesticide spray schedules that involved calendar spraying whether the pest was present or not (Atwal 1976, Srivastava and Butani 1998). This approach has led to increased dependence on pesticides and consequent adverse effects such as higher costs of production, environmental pollution, destruction of natural enemies, and development of pesticide resistance in BSFB. The current pesticide use is not only non-sustainable but, if continued will adversely affect brinjal and other vegetable production. So, there is an urgent need for developing alternative control strategies.

Hence keeping the above points in view, the present investigation was undertaken to know the weakest link in life cycle of *L. orbonalis* at which it can be effectively controlled with the following objectives.

1. To study biology of *L. orbonalis* on brinjal under laboratory conditions.
2. To study the seasonal incidence of *L. orbonalis* on brinjal and weeds in and around brinjal fields.

CHAPTER – II

REVIEW OF LITERATURE

Brinjal shoot and fruit borer (BSFB) was first described as *Leucinodes orbonalis* by Guenee in 1854 and it was designated as the type species of the genus by Walker in 1859 (Alam *et al* 2003). An account of genus *Leucinodes* was first given by (Hampson 1946). Lefroy (1909) identified *L. orbonalis* as pyralid moth and classified it under order Lepidoptera (Family - Pyralidae). However, Srivastava and Srivastava (1957) described it under the family Pyraustidae.

There are no known synonyms of *L. orbonalis*, but several other species of *Leucinodes* have been described. *L. orbonalis* is practically a monophagous pest, feeding mainly on brinjal, however various other plants belonging to family Solanaceae are also reported to be the hosts of this pest. They include tomato (*L. esculentum*), potato (*S. tuberosum*), selected nightshades (*S. nigrum* and *S. indicum*) and turkey berry (*S. torvum*). Considerable efforts have been made to control this pest through the use of chemicals as it is an internal feeder (Banerjee and Basu 1955, David 1963). But the use of chemicals is not much economical as it contributed to 32 per cent of the total cost of production in addition to causing environmental degradation. Further the use of highly systemic poisons at very high frequency makes the vegetable poisonous, ecologically unsafe and economically unviable. Various biocontrol agents as parasitoids, predators and entomopathogens have also been used for the control of this pest but they too do not seem to play any significant role in keeping BSFB damage under reasonable control (Srivastava and Butani 1998). Thus, the best way to manage this pest is by knowing the weakest link in its life cycle. This will in turn increase profit, protect the environment against use of pesticides and improve public health. Different sources of carryover of *L.orbonalis* have been reported as the moths emerge from pupae in soil or moths migrate from neighbouring brinjal crops or brinjal stalks of previous crops. This pest was also reported to attack potato crop in Mysore state by Nair (1967). In young plants, caterpillars were reported to bore inside petioles and midrib of large leaves. As a result the affected leaves dropped off (Butani and Jotwani 1984).

Atwal (1976) reported that this pest damaged the brinjal fruits particularly in autumn in very severe form and the whole crop was destroyed. Abrol and Singh (2003) reported maximum damage of up to 95 per cent by this pest during the rainy season. This pest was active throughout the year but its activity was adversely affected by severe cold.

2.1 Biology of *L. orbonalis*

Hussain *et al* (1937) revealed the appearance of *L. orbonalis* in Punjab and studied the biology of this pest under Punjab conditions. They observed that the incubation period of

this pest was 3 to 4 days, duration of larval stages varied according to the season from 8 to 26 days in different months and pupal period ranged between 6 to 13 days. A single female of this moth was capable of laying 40 eggs in her life span and eggs were laid singly or in clusters on the undersurface of brinjal leaves.

Lall and Ahmed (1965) stated that this pest maintained its breeding activities on brinjal plants during crop season (September to March) and on weeds (*S. nigrum* and *S. xanthocarpum*) during off season (April to August). The life cycle varied from 26 to 39 days with ten generations in a year and an individual laid 92.50 to 233 eggs. The highest fecundity per female (233 eggs) and lowest female longevity (1.70 days) was observed during May while lowest fecundity (92.50 eggs) and highest longevity (2.70 days) was observed in February. Low temperature and high humidity had adverse affects on the fecundity of the moths. Average incubation period was 4.87 days, larval period 16.85 days and pupal period 8.88 days. They further reported that the freshly laid eggs were creamy to white in colour with 483.27µ diameter which changed to deep orange before hatching. The freshly hatched larvae measured 934.52µ long and 141.98µ wide whereas full grown larvae measured an average of 18.00 to 20.00 x 2.50 x 3.00 mm, the freshly formed pupa was pinkish which later changed to dark brown and measured 10.00 to 14.00 mm x 3.00 to 4.00 mm. Biology of this pest was also studied by (Saxena 1965, Atwal 1976).

Atwal and Verma (1972) conducted an experiment on the development of *L. orbonalis* in relation to different levels of temperature and relative humidity and observed that 30° C temperature and 70 to 90 per cent relative humidity were more conducive for the survival of this pest and there was no hatching of eggs at 40° C. They also studied the development of BSFB on the long and round fruited varieties of brinjal and tomato and observed that brinjal provided better nourishment to the pest than tomato as the survival percentage was lower on tomato. Maximum damage due to this pest was reported during July to September and a maximum of 9 larvae were reported from a single fruit during this period.

Allam *et al* (1982) studied the biology of BSFB and reported six larval instars. They further reported that the eggs were laid mostly on the underside of the leaves. The total larval period lasted 9.00 to 13.00 days and the pupal period lasted 7.00 to 11.00 days with an average of 9.00 days. Pupation took place on glass jars, soil, lid of the jars and sometimes on the fruits, indicating no preference. The male moths lived for 1.00 to 2.00 days and the females for 2.00 to 3.00 days. Total life cycle of this pest was 19.00 to 28.00 days.

Mehto *et al* (1983) also conducted experiments on the biology of BSFB, *L. orbonalis*, and reported that the pre-oviposition and oviposition periods were 1.20 to 2.10 and 1.40 to 2.90 days, respectively.

Patil (1990) studied different techniques for mass rearing of BSFB under laboratory conditions by providing natural and synthetic diet. He found that when reared on natural food, average longevity of the adults was 3.00 to 6.00 days as compared to those fed on sucrose (5 per cent) and glucose (5 per cent) where longevity was found to be 2.90 and 2.20 days, respectively. On an average 190 eggs were laid by a pair of moths fed on 5 per cent honey solution. When larvae were fed on semi synthetic diet, 66.67 per cent pupation, 18.50 days of larval period and 53.33 per cent normal adult emergence was reported.

Baang and Corey (1991) studied the life history of *L. orbonalis* on egg plant under laboratory conditions and reported that flat-oval eggs were laid most frequently at night. The average number of eggs laid per female was 121.50 ± 0.44 and of these 79.24 per cent were viable. There were 6 larval instars. The egg, larval and pupal period were 6.00 ± 0.05, 15.38 ± 0.21 and 11.50 ± 1.11 days, respectively. The average longevities of males and females were 4.00 ± 0.70 and 7.50 ± 0.26 days, respectively.

Sandanayake and Edirisinghe (1992) determined the larval instars by measuring the size of the head capsules. They also studied larval distribution on brinjal and concluded that the first instar larvae were found in flower buds and flowers; second instar larvae in all susceptible parts of the plant; larvae were confined to the shoots and fruits in the third and fourth instars; and fifth instar larvae were found only in the fruits.

Kumar and Johnsen (2000) reared *L. orbonalis* on natural diet in laboratory to ascertain details of their life cycle and habit and reported that adults were nocturnal in habit, as most of their feeding, mating and egg laying activities occurred during night between 2.00 to 6.00 hours and lasted for about 16.00 minutes. Eggs were laid during the early hours of the next morning. The eggs were laid either singly or in batches on the ventral surface of the leaves. The larvae on hatching crawled about 30.00 to 60.00 minutes to locate a suitable site for penetration, after which they bored inside the top shoot and tender fruits. The fruits were always preferred over shoot. A total of 6 larval instars were recorded. Observations were taken on the pre-ovipositional and post-ovipositional duration and it was revealed that climatic conditions played an important role in the life cycle of the borer. As with the increase in temperature and decrease in humidity, fecundity increased and duration of life cycle decreased. The larval period constituted the longest duration, followed by pupal and egg stages. The total duration of the life cycle was 27.07 ± 0.75 days.

Singh and Singh (2001a) studied the development of BSFB at medium high altitude hills of Meghalaya. They reported that the mating of adults occurred more than once for a female and took place in night or very early hours in the morning. The laying of eggs started on the same day of mating, but the number of eggs gradually decreased with each passing day. On an average, 174.95 eggs were laid by a female, mostly singly. The incubation period

of the eggs was reported to be 5.65 days. The viability of eggs was reported as 83.00 per cent, the average pre-ovipositional period was 1.35 days, and average larval period was 18.66 days with 5 larval instars. The average pre-pupal and pupal period was 2.08 and 10.43 days, respectively and the average life span of male and female moth was 3.53 and 5.80 days, respectively. The life cycle of *L. orbonalis* in one generation was completed in 36.82 days. They further reported that the female mates usually more than once in her life span.

Singh and Singh (2001b) also conducted an experiment to note down the number of generations of BSFB in a year and reported that there were eight generations of this pest in a year. The first generation started from 25th April and ended on 2nd June, second generation from 5th June to 11th July, third generation from 14th July to 16th August, fourth generation from 18th August to 18th September, fifth generation from 20th September to 28th October, sixth generation from 31st October to 19th December, seventh generation from 22nd December to 8th March and 8th generation from 11th March to 22nd December. The life cycle of these generations were reported to be 36.43, 35.15, 33.56, 30.66, 35.95, 48.18, 76.14 and 42.07 days, respectively. It was further reported that the 7th generation was longest as pupae went under diapause stage due to low temperature and adults emerged only in March. The shortest developmental period was recorded in the 4th generation because of suitable weather conditions for the development of the borer. Fecundity was also highest in the 4th generation with 249 eggs per female and also the viability of 99.80 per cent was reported during this generation.

Singh and Singh (2003) studied the effect of weather parameters on the development of *L. orbonalis* on brinjal at the medium high altitude hills of Meghalaya, India. The average highest fecundity, i.e. 240.30 eggs, was recorded in the month of August when the average maximum and minimum temperature and relative humidity were 27.45°C, 18.90°C and 90 per cent, respectively. The average lowest fecundity, i.e. 88 eggs per female, was recorded in November when the average maximum and minimum temperature and relative humidity were 21.95°C, 11.90°C and 86.75 per cent, respectively. It was reported that all the weather parameters either alone or in combination affected the ovipositional period except for the maximum temperature. Humidity alone as well as in combination with the temperatures had the significant effect on the larval period. Both the temperatures had no significant effect on the pre-pupal period and pupal period either alone or in combination; however, humidity either alone or in combination with temperatures had effect on both periods. The longevity of male was found to be affected by both the maximum and minimum temperatures either alone

or in combination with humidity; otherwise, there was no significant influence of humidity alone on the longevity of male. Similar effect was observed for the longevity of female moth with the weather parameters.

Jat *et al* (2003) reported that BSFB laid eggs either singly or in batches of 2 to 4 near the veins on the undersurface of leaves with average number of 174 eggs. The length and width of the eggs was reported to be 0.81 mm and 0.57 mm respectively. Pre-ovipositional, ovipositional and post-ovipositional periods of *L. orbonalis* was 7.40 hours, 2.43 and 1.26 days, respectively. The larvae passed through five instars and the fifth instar larva had three distinct segments of thorax and five pairs of well developed prolegs. The incubation, larval and pupal periods were 4.30, 12.83 and 9.42 days, respectively. The pupation took place on the glass jars, soil, muslin cloth, inside the fruits and on the leaves of the plants. The pupa was dark brown in colour with eight hook shaped fine spines at the posterior end of the abdomen. The longevity of the male moth was 1.82 days while female lived for 3.12 days. The mean time taken from egg to adult stage was 25.87 days.

Ghosh *et al* (2005) studied biology of this pest under the Gangatic plains of West Bengal, India and they reported the incubation period, larval period and pupal period as 5.08 ± 0.30, 15.43 ± 0.43 and 13.05 ± 0.47 days, respectively. The duration of life cycle was 33.56 ± 1.21 days. They further concluded that the temperature had the profound influence on the different biological stages of *L. orbonalis.*

Anjana *et al* (2007) studied the biology of *L.orbonalis* in the mid-hill zone of Himachal Pradesh and revealed that this pest completed 8 to 9 overlapping generations per year. The larval period was 12.00 to 18.00 days in most of the generations except the winter generation in which the fifth instar caterpillars overwintered for a period of about 134.00 days. The total life cycle was completed in 22.00 to 30.00 days between March and September.

Kavitha *et al* (2008) reported that *L. orbonalis* completed its life cycle in 35.27 days and the pre-oviposition, oviposition, incubation, larval and pupal periods were 1.35, 2.01, 2.98, 16.32 and 8.01 days, respectively. The number of eggs laid was reported to be 170. The longevity of male and female was 3.50 and 5.70 days.

According to Wankhede *et al* (2009) the pre-oviposition, oviposition and post-oviposition periods of *L.orbonalis* were 7.10 ± 0.29 hours, 2.30 ± 0.21 and 1.50 ± 0.18 days, respectively. The larvae passed through five instars. The incubation, larval and pupal periods were 3.80 ± 0.18, 13.80 ± 0.70 and 10.20 ± 0.36 days, respectively. They also reported that pupation took place on the glass jars, soil, muslin cloth, sometimes inside the fruits and on the leaves of the plants. The longevity of male moth was 1.70 ± 0.17 days while female lived for

3.30 ± 0.32 days. The mean time taken from egg to adult stage was 27.80 ± 1.24 days. Number of eggs laid by a female was on an average of 120.30 ± 3.04.

Varma and Anandhi (2009) during their experiment on biology and morphometry of BSFB revealed that the egg incubation period was 4.00 ± 1.05 days. Length and breadth of the egg was reported to be 0.60 ± 0.04 and 0.36 ± 0.03mm, respectively. The duration of 1st, 2nd, 3rd, 4th, 5th and 6th larval instars was 1.40 ± 0.52, 2.00 ± 0.82, 1.90 ± 0.57, 1.90 ± 0.74, 2.20 ± 1.35 and 1.70 ± 0.67 days, respectively. The total larval duration was 11.10 ± 3.28 days, pre pupal period 1.40 ± 0.52 days and pupal period 5.70 ± 1.64 days. The full grown larvae measured 18.10 ± 1.20 mm in length and 3.16 ± 0.12 mm in breadth. The adult longevity of male was 4.28 ± 1.38 days and of female 5.71 ± 1.25 days and the pre-oviposition, oviposition and post-ovipostion periods were 0.28 ± 0.49, 3.00 ± 0.58 and 2.43 ± 1.40 days, respectively. Body length of male and female was 9.70 ± 3.65 and 9.05 ± 0.76 mm, respectively. The average fecundity was 149.42 ± 70.82 eggs per female.

Radhakrishore *et al* (2010) studied the biology of BSFB and revealed that the male and female moth measured 18.69 ± 1.45 mm and 19.37 ± 1.45 mm, respectively. The average number of eggs laid by single female varied from 15 to 137 eggs in 2.00 to 5.00 days. The larvae passed through six instars. The incubation, larval and pupal periods were 5.22 ± 0.07, 16.86 ± 0.02, 9.09 ± 0.30 days, respectively. The adult longevity of the pest was 5.38 ± 0.20 days. The period from egg to adult stage was 41.88 ± 6.03 days.

Rahman *et al* (2011) conducted an experiment to study growth and development of BSFB on two natural and one artificial diet. The 2nd instar larvae were used for the study. They observed that among the different diets, brinjal was the best for growth, development and longevity of larvae and pupae and prolongation of larval and pupal period. The mean length of full grown larvae fed with brinjal was 9.37, 9.80 and 12.44 mm from generations 1, 2 and 3, respectively. The larval and pupal duration on brinjal food media were 13.10 and 8.17, 12.80 and 8.23 and 13.10 and 8.03 days in generations 1, 2 and 3, respectively. The percentages of adult emergence from pupae raised in brinjal were 65.38, 47.95 and 33.78 in generations 1, 2 and 3, respectively.

Mathur *et al* (2011) studied the influence of temperature and relative humidity levels on the developmental stages and growth index of BSFB in semi arid regions of Rajasthan and observed that the incubation period increased with the fall in temperature and percentage hatchability reduced as winter approached. Development of BSFB was favored by moderate to high temperature with highest growth index of 1.09 during the period of June to August. Thus there was maximum incidence of BSFB during rainy season.

Prithwiraj *et al* (2012) studied the biology of BSFB under laboratory conditions at 27 ± 1ºC and 80 ± 5 per cent RH. They observed that larval period, pupal period, adult longevity and mean length of generation were 16.20, 7.60, 3.80 and 26.90 days, respectively.

Onekutu *et al* (2013) studied the biology of BSFB on garden egg, *Solanum gilo*, at 27 ± 3°C and 85 ± 4 per cent RH. Data on developmental period of immature stages and reproductive parameters and sex ratio were collected and it was found that developmental stages consisted of an egg, five larval instars, pupa and adult. Developmental periods observed were eggs (5.93 days), 1st instar (1.00 day), 2nd instar (1.16 days), 3rd instar (1.48 days), 4th instar (2.63 days), 5th instar (4.46 days), pupa (11.20 days), female (4.14 days) and male (4.31 days). The reproductive parameters observed were incubation period (5.93 days), pre-oviposition period (1.19 days), oviposition period (2.71 days) and post-oviposition period (3.75 days). The male to female ratio was 1:2 and actual fecundity and potential fecundity per female were 123 and 207 eggs, respectively. Laboratory studies revealed that BSFB, *L. orbonalis*, completed its life cycle in 28.17 days.

The perusal of the above studies revealed that biology of *L. orbonalis* varied under agroclimatic conditions and need to be conducted for every region.

2.2 Biometric analysis of *L. orbonalis*

Jethva and Vyas (2009a) revealed that the measurements of head capsule width of the larvae fell into five well defined groups and each indicated an instar. The mean observed (0.23 to 1.48 mm) and calculated head capsule width (0.25 to 1.58 mm) and progression factors were close to each other (1.60 and 1.59), which indicated that an increase in head width during successive instars was in geometrical progression, when larvae were reared on brinjal and it followed the Dyar's law.

Jethva and Vyas (2009b) reported that the increase in head width during successive instar was in geometrical progression, when larvae were reared on tomato and it followed the Dyar's law. The mean values of the observed (0.21 to 1.39 mm) and calculated head capsule width (0.24 to 1.51 mm) and progression factors were close to each other.

Jethva *et al* (2011) conducted an experiment on the biometric analysis of *L. orbonalis* to test the applicability of Dyar's law to its larvae, when reared on pea at a constant temperature of 26 ± 1ºC and it was revealed that the measurements of the head capsule width of the larvae fell into five well defined groups each indicating an instar, when larvae were reared on pea. The mean values of the observed (0.21 to 1.30 mm) and calculated head capsule width (0.22 to 1.35 mm) and progression factors were close to each other which indicated that an increase in head width during successive instar was in geometrical progression, when the larvae were reared on pea and it followed the Dyar's law. The progression factors determined from the body length and width indicated great deviation. The

multiple correlation coefficient (R^2=0.98) also indicated a very high predictability of head capsule width through larval body length and width.

2.3 Seasonal incidence of *L. orbonalis* Guenee

No studies have been reported on the seasonal incidence of *L. orbonalis* on brinjal under Punjab conditions. Studies carried out in other Indian states and abroad are reviewed here. Rahman (1997) reported that the per cent fruit infestation caused by the pest was up to 90.86 per cent. Only the larvae of this pest caused 12.00 to 16.00 per cent damage to shoots and 20.00 to 60.00 per cent to fruits (Alam 1970, Maureal *et al* 1982). The pest was very active during the rainy and summer season and often caused more than 90.00 per cent damage (Ali *et al* 1980, Kalloo 1988). The yield loss has been estimated to be up to 86.00 per cent (Ali *et al* 1980) in Bangladesh and up to 95.00 per cent (Naresh *et al* 1986) in India. The main reason for such a high loss due to this pest was its survival on the various alternate host plants. The various host plants of the pest which were reported include major host plants viz. *S. melongena, S. tuberosum*; minor hosts viz. *Ipomoea batatas, L. esculentum, Pisum sativum var. arvense, S. indicum, S. myriacanthum, S. torvum* and wild hosts viz. *S. gilo* and *S. nigrum.*

The temperature and relative humidity played an important role while assessing the pest status and its natural enemies and for developing eco-friendly pest management approach against *L. orbonalis* (Georghia and Taylor 1978). Mall *et al* (1992) reported that the temperature and relative humidity ranging between 20 to 25^0C and 50 to 72 per cent, respectively favored, while rainfall reduced the multiplication of *L. orbonalis.*

Tariq *et al* (1992) studied the correlation between *L. orbonalis* infestation and abiotic factors like maximum temperature, minimum temperature, relative humidity and rainfall. They concluded that infestation had significant and positive correlation with mean minimum temperature. With a decrease in 1ºC mean minimum temperature there was a decrease of 1.71 per cent and 1.81 per cent fruit infestation during two years of the experiment. A positive but non significant correlation was found between maximum temperature, rainfall and fruit infestation. Relative humidity had no significant contribution towards increasing or decreasing fruit infestation. The infestation was recorded maximum during August. A total of 41.72 and 38.05 per cent fruit infestation was noticed throughout the crop growth of brinjal during two years of study. Mean fruit infestation during both years of study was 39.89 per cent.

Patnaik (2000) studied the seasonal abundance of BSFB, *L. orbonalis*, in Orissa and found that in July planted brinjal crop, the peak infestation levels ranged from 59.20 to 75.50 per cent and was recorded at 64.00 to 88.30 days after planting, during September and

October. Relative humidity was the only weather parameter to have a direct effect on pest seasonal abundance. Peak infestation of flower buds occurred during March (68.00 per cent) and August (29.20 per cent).

Jat *et al* (2002) reported that the infestation of shoot borer started from fourth week of August and reached to its peak in the last week of September. Whereas fruit borer started damaging from first week of October, peaked in the fourth week of October and continued upto second week of December. Significant positive correlation was observed between fruit borer infestation and maximum temperature, while minimum temperature had no effect. The relative humidity had no effect on fruit infestation.

Ishar *et al* (2007) studied the seasonal abundance of this pest on the summer crop of brinjal and revealed that incidence of the pest on the shoots commenced in the 14th Standard Week (SW) with 4.28 per cent infestation which reached its maximum 23.16 per cent in 17th SW when mean maximum and minimum temperatures were 34.9°C and 24.0°C and the mean relative humidity was 61.00 per cent in the morning and 26.00 per cent in the evening.

Mahesh and Men (2007) studied the seasonal incidence of shoot and fruit borer in Maharashtra, India and reported that the infestation commenced from August with 21.20 per cent infestation and reached its first peak during mid-October with 35.30 per cent infestation at temperatures ranging between 21.40 and 33.00°C, relative humidity of 45.00 to 86.00 per cent with 2.70 mm rain and 7.00 hours of sunshine.

In a study on seasonal incidence of *L. orbonalis* on brinjal grown in Andhra Pradesh, India, Naik *et al* (2008) showed that the incidence of BSFB, in terms of shoot infestation, was maximum during the third week of February and the incidence had no significant relationship with temperature, relative humidity and rainfall but had a significant relationship with population of coccinellids and spiders.

Naqvi *et al* (2009) studied seasonal incidence of BSFB in hyper arid region of Rajasthan and revealed that the infestation of *L. orbonalis* in brinjal shoots started in the 1st week of August and remained up to 2nd week of October, with the peak in 2nd week of September. The infestation in fruits was recorded in the 2nd week of September and remained up to 3rd week of October. The infestation increased gradually and reached the maximum in the 1st week of October i.e 63.09 per cent on number and 51.45 per cent on weight basis. The infestation of fruit borer started declining and persisted only up to 3rd week of October. The maximum temperature had positive significant effect on the fruit infestation whereas negative significant correlation was computed between borer infestation and maximum temperature. Relative humidity had positive significant effect on the shoot and fruit borer while rainfall had no effect on the infestation by this pest.

Ghosh and Senapati (2009) reported that this pest was found to be most active during summer and the rainy season, particularly during May–August, and caused 49.50 to 81.00 per cent damage to fruits in the sub-Himalayan region of West Bengal, India. Peak infestation (81.00 per cent fruit damage) was noticed in the first week of June (22nd SW), when the mean temperature, mean relative humidity and weekly rainfall were 27.80°C, 79.20 per cent and 81.20 mm, respectively. The pest became less active during winter months particularly in December–January. Borer infestation showed a significant positive correlation with maximum and mean temperature, minimum and mean relative humidity and rainfall, whereas with maximum relative humidity the correlation was negative but non-significant.

Masarrat-Haseeb *et al* (2009) noticed peak infestation of 42.47 per cent in 3rd week of November and a declining trend in population with the advent of winter season which reached to zero in 2nd SW of January.

A field study was conducted by Singh *et al* (2009) on the population dynamics of *L. orbonalis* on brinjal in Canchipur, Manipur, India, during 2003 and 2004. In this study it was observed that the borer infested the crop from early vegetative stage and continued up to crop maturity. Its infestation commenced first on shoots from the 2nd week of April with 9.70 per cent in 2003 and 11.60 per cent in 2004 and reached its peak on shoot during the 2nd week of June in 2003 and 3rd week of May in 2004 with 25.80 per cent and 31.40 per cent infestation, respectively. The borer infestation on brinjal fruit was noticed from 3rd week of April and it was 24.64 per cent in 2003 and 12.50 per cent in 2004. Analysis of correlation coefficient between the infestation percentage of borer and weather parameters revealed that the mean temperature and relative humidity had significant positive influence on the population incidence of the borer. The sunshine hours and the wind speed showed significant negative effect on the pest, whereas rainfall did not significantly influence the incidence of borer.

Varma *et al* (2009) recorded the highest population of *L. orbonalis* in Allahabad, U.P. in the 5th and 2nd week of December during first and second year of study, respectively. The borer incidence was positively related to maximum relative humidity, rainfall and wind speed during first year and with maximum relative humidity and sunshine hours in second year. The number of damaged fruits and fruit weight loss varied from 3.76 to 45.45 per cent and 3.00 to 67.71 per cent in first year and 5.71 to 44.26 per cent and 3.00 to 51.33 per cent in second year.

Khuhro *et al* (2011) reported that brinjal was attacked by borer from September to February. They reported maximum infestation of 46.60 per cent in the 1st week of February and minimum infestation of 6.60 per cent was recorded in the 4th week of October and 2nd week of November.

Singh *et al* (2011) reported that the incidence of the shoot and fruit borer started in April and continued until the end of June. They reported maximum shoot infestation in the 3rd and 2nd week of June. The maximum fruit infestation was recorded during the 2nd week of June. Correlation studies revealed that the average relative humidity was significantly positive, whereas the average sunshine showed significant negative correlation with the infestation of the pest.

Kumar and Singh (2012) reported that the infestation of borer started in third week of August with peak of 83.30 to 86.60 per cent on top shoots in third week of September, with an intensity of 1.9 to 2.0 larvae/plant. On initiation of fruiting stage, there was a continuous decline in the shoot infestation which disappeared during fruiting stage in the end of October. As the borer infestation shifted to the fruits reaching at 60.00 to 66.60 per cent on the basis of its counts and 56.50 to 56.60 per cent by weight in the second week of October, the infestation gradually declined with the advent of winter season and was completely wiped out by the end of November. The role of temperature, rainfall, relative humidity (morning) in increasing infestation and intensity on shoots and fruits was very conducive but relative humidity (evening) responded negatively. The apparent losses caused by borer on fruits were 19.40 to 20.20 per cent whereas total losses were up to 35.20 to 36.40 per cent, out of which avoidable losses were 34.00 to 36.10 per cent but 0.30 to 0.40 per cent losses were unavoidable as could be controlled even after application of protection technology.

Meena *et al* (2012) conducted a trial to know the extent of damage caused by BSFB and revealed that borer infestation started from 4th to 11th SW. The peak period of shoot infestation was observed in 9th SW (5.40 per cent) and 7th SW (4.60 per cent) followed by 8th SW (4.50 per cent). The incidence of fruit borer started from 10th SW and continued till last picking. Peak infestation of fruit borer was observed in 18th SW (43.30 per cent) and 17th SW (40.10 per cent). The average extent of shoot damage ranging from 1.40 to 4.00 per cent and fruit damage from 14.90 to 35.20 per cent were recorded.

Tiwari *et al* (2012) conducted an experiment to know the influence of various weather parameters like temperature, relative humidity, rainfall, sunshine hours etc. on the population fluctuation of BSFB and reported that incidence of BSFB was significantly positively correlated with sunshine hours.

2.4 Alternate host plants of *L. orbonalis*

Fletcher (1916) found *L. orbonalis* boring the shoots of potato and reported to cause 10-15 per cent infestation. The shoots were bored in the month of November and December. Fletcher (1921) reared this pest under laboratory conditions on *S. nigrum* and *S. xanthocarpum*. Maureal *et al* (1982) reported that *L. orbonalis* was able to develop on both

potatoes and tomatoes but it was not reported as a pest of these crops unless subjected to hunger stress.

Host range of *L. orbonalis* was also studied by Ardez *et al* (2008) on seven crops, namely aubergine (*S. melongena*), white potato (*S. tuberosum*), sweet potato (*Ipomoea batatas*), tomato (*L. esculentum*), okra (*A. esculentus*), cowpea (*Vigna sinensis*) and black nightshade (*S. nigrum*). It was found that BSFB was able to successfully complete its life cycle on aubergine, black nightshade and white potato. The black nightshade was found to serve as alternate host for BSFB in the month of March and April and was confined to both shoots and fruits. It completed its lifecycle in 29 days with 38 eggs on *S. nigrum*.

Shukla and Khatri (2010) also studied the effect of different host plants namely *S. melongena, L. esculentum, Abelmoschus esculentus, S. tuberosum, S. nigrum, Cynodon indicum, Oscimum basilicum* and *S. indicum* on the development of BSFB.

Boopal *et al* (2013) conducted an experiment to study the biology and survival of this pest on alternate hosts as tomato and potato in the absence of natural host i.e brinjal and revealed that *L. orbonalis* can complete its life cycle in comparative crop like potato other than its natural host under laboratory conditions.

Thus, the above studies revealed that the climatic factors play a major role in the incidence of borer and the incidence varied over the months.

CHAPTER – III

MATERIAL AND METHODS

The present studies on "Biology and seasonal incidence of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee" were conducted during 2011-12 at the Entomological Research Farm and the Acarology laboratory of the Department of Entomology, Punjab Agricultural University, Ludhiana.

3.1 Raising of crop

Brinjal crop was sown at Entomological Research Farm, Punjab Agricultural University, Ludhiana. Three successive crops of brinjal were grown for recording the seasonal incidence during different seasons and for getting regular supply of food throughout the experiments. The first crop was raised in mid May (date of transplanting (DOT) – 16.5.2011), second in September (DOT – 2.9.2011) and third in February (DOT- 2.2.2012). *Punjab Sada Bahar* variety of Brinjal was used for the trials. The seedlings of this variety were procured from Department of Vegetable Science, Punjab Agricultural University, Ludhiana. The crop was raised as per the recommended Package of Practices for cultivation of vegetable crops, except that no spraying was done on the crop (Anonymous 2012).

3.2 Raising of insect

Field collection of larvae of BSFB was made from Research Farm of the University and fields in and around Ludhiana. The larvae collected were transferred to the plastic vials of 25 ml size containing fresh pieces of brinjal fruit. The vials were then covered with lid and the food was changed daily in the morning hours to prevent fungal contamination till the fifth instar larvae got ready for pupation. As the larvae fed on brinjal pieces by making tunnels and excrete exuviae and fecal matter, so there was need to change the food in the vials and also the vials daily. The full grown fifth instar larvae were shifted to glass jar, containing sand, covered with muslin cloth for pupation. The sand in the jar was kept moist by sprinkling water over it to provide sufficient moisture for the survival of pupae. The sand was autoclaved to prevent any pathogenic infection to the pupae.

The adults that emerged from pupae were sexed on the same day by observing the body size and presence of tuft of hairs at the tip of the abdomen. These adult moths were used for the further studies. One pair of freshly emerged male and female moth was released in glass jar (15cm x 10cm) having filter paper placed at the bottom. Fifteen such glass jars were prepared consisting of five jars in each replication and there were three replications. The glass jars were then covered with black chart from outside and the cotton swabs dipped in 5 per cent honey solution were hung from the upper side with the help of pins to provide food to the adults. The mouth of the glass jars were covered with muslin cloth. A 50 ml plastic vial

containing a twig of brinjal plant dipped in water was also placed in the glass jar to provide natural environment for adults to facilitate oviposition.

The eggs thus obtained were examined daily to record the incubation period of eggs and also for emergence of neonate larvae. To record the incubation period three replications were made consisting of ten eggs in each replication. The larvae that hatched from the eggs on the same day were used for biological studies. All the parameters were recorded at room temperature and relative humidity during three different months i.e June, August and October. The mean temperature and relative humidity recorded were 31.45ºC, 29.65 ºC and 25.33 ºC and 59.00, 79.25 and 65.88 per cent during June, August and October, respectively.

3.3 Biological studies

3.3.1 Incubation period

To observe the incubation period freshly laid eggs were observed daily for the emergence of neonates.

3.3.2 Larval period

Ten neonate larvae were transferred by camel hair brush in small vials containing pollen grains of flowers of brinjal. The food in the vials was changed daily in the morning hours to prevent fungal growth. On formation of second instar larvae, the food was changed from pollen to brinjal slices as BSFB is an internal feeder and feeds by making tunnels in the fruit. The time when full grown larvae stopped feeding and became inactive was considered as the termination of the larval and initiation of pupal stage.

3.3.3 Pupal period

The fully grown fifth instar larvae were transferred to small vials having moist layer of autoclaved sand and observed daily in the morning hours to study the pupal period during different months of the year.

3.3.4 Oviposition period and fecundity

The adults that emerged were sexed by examining presence of tuft of hairs at the end of abdomen and their body size. The males were smaller in size and do not possess abdominal tuft. The females were larger in size and had tuft of hairs at the tip of abdomen. One pair was released in each glass jar (15cm x 10cm) covered with black chart from outside and the cotton swabs dipped in 5 per cent honey solution were hung from the upper side with the help of pins to provide food to the adults. These pairs were observed daily for studying the oviposition period and fecundity of the female. To determine the oviposition period, the eggs laid by female in the jars were observed daily till the death of the female moths. The fecundity was calculated by counting the total number of eggs laid by the female on the filter paper, glass jar, brinjal leaves on the twig placed in the jar and the muslin cloth.

3.3.5 Adult longevity

To determine the longevity of adults, both male and female, observations were recorded daily from their emergence till death.

3.3.6 Sex Ratio

Sex ratio was observed by counting the number of male and female moths emerged.

3.3.7 Sex differences in pupal stage

For determining the sex differences in the pupal stage, the observations were made on the last abdominal segment of the pupae. In case of female the distance between genital slit and last abdominal segment was less whereas in case of male pupae the distance between genital slit and last abdominal segment is more (Plate 1). Ten pupae were examined for each sex.

3.3.8 Biometric analysis

For biometric analysis each stage of BSFB was examined and data regarding their length, width and head width was recorded using image analysis system under stereozoom microscope (Carl Zeiss Discovery.V8).

3.4 Seasonal incidence

Weekly observations were made on the number of infested shoots and fruits per ten plants throughout the year for recording the seasonal abundance and the peak activity period of the insect. *Punjab Sada Bahar* variety of brinjal was used for the trial; the plot size was kept as 4m x 5m with three replications. The observations were recorded from ten randomly selected plants from each plot. All the above ground plant parts were examined thoroughly to observe the damage caused by this pest. Besides seasonal abundance, observations were also made on its incidence on the weeds present in and around the brinjal fields. Data on weather parameters viz. maximum and minimum temperature, sunshine hours, rainfall and relative humidity were obtained from the meteorological laboratory of the School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana. The incidence was correlated with meteorological parameters and regression was also worked out.

3.4.1 Nature of Damage

The nature of damage caused by the larvae was studied by close observations in the laboratory and the field. The feeding behaviour of larvae was recorded. Damage to the flowers, shoots and fruits was observed.

3.5 Host range

Regular field surveys were made to find out the other alternate host plant of this insect. In confirmation, counted number of larvae were released on possible host plants viz. *S. nigrum* (common name - *makoh*), *P. minima* (common name – *bhumbla*), tomato, *L.*

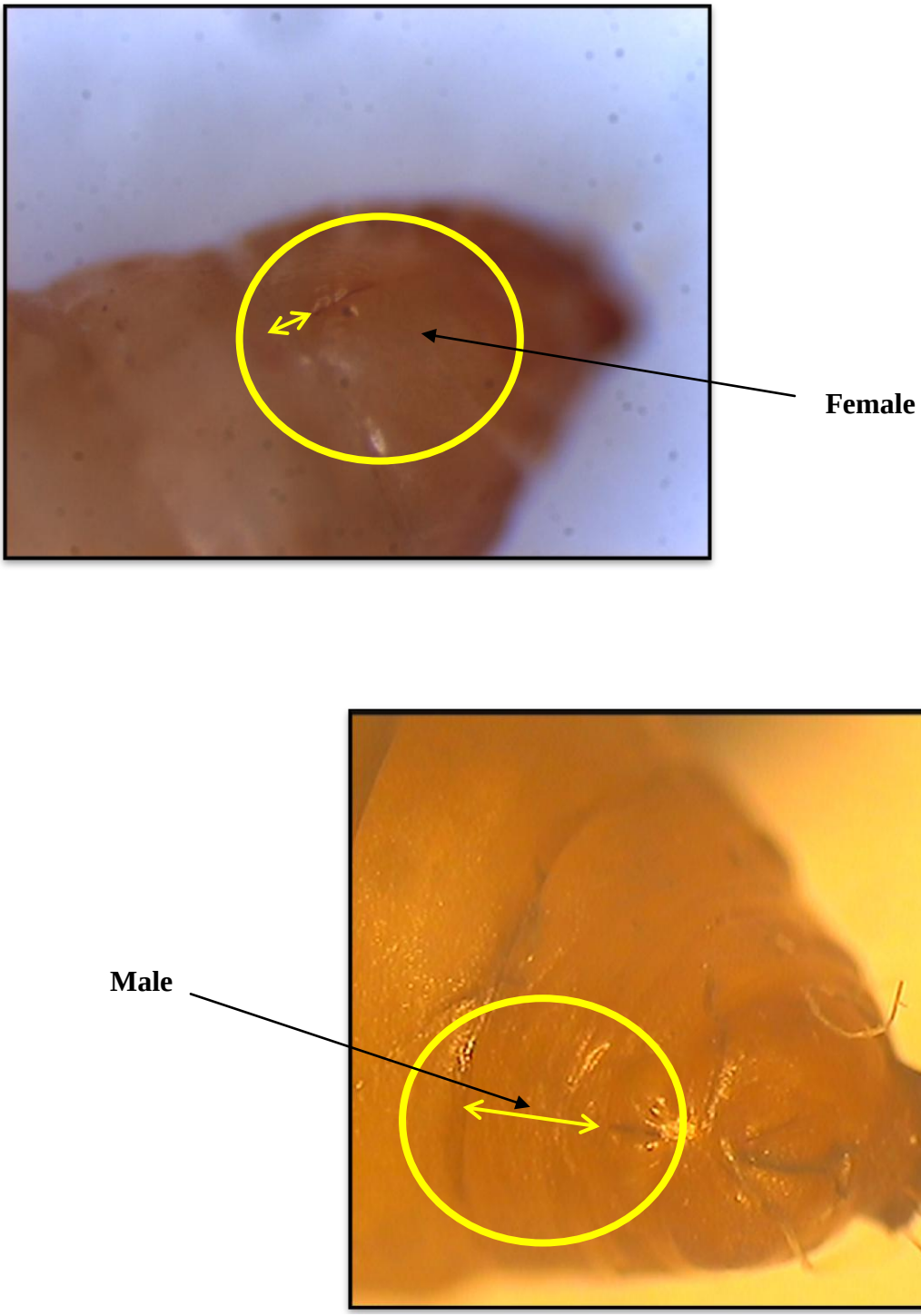


Plate 1: Male and Female pupae of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee

esculentum and potato, *S. tuberosum* (all belonging to Family Solanaceae) and *Achyaranthes aspera* (common name – *puthkanda*) (Family Amaranthaceae) at Entomological Research Farm and the Acarology laboratory of the Department of Entomology, Punjab Agricultural University, Ludhiana to record its survival on these plants. Observations were taken daily to record the feeding/survival of this pest on these plants. Attempts were made under laboratory conditions to observe the survival of this pest on slices of *S. tuberosum* and *L. esculentum.* For this, fresh slices of potato and tomato were provided as food to larvae confined to rearing jars.

3.6 Statistical analysis

The experimental data on biology of *L. orbonalis* was analysed statistically by applying Complete Randomized Design and for determining the seasonal incidence correlation of shoot and fruit infestation with different weather parameters was determined and regression was worked out.

CHAPTER IV

RESULTS AND DISCUSSION

The study on "Biology and seasonal incidence of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee" was conducted during 2011-12 in three different months at the Entomological Research Farm and the Acarology laboratory of the Department of Entomology, Punjab Agricultural University, Ludhiana. The primary objective of the study was to find out the total developmental period of brinjal shoot and fruit borer (BSFB) under laboratory conditions and to observe the seasonal incidence of this pest under field conditions. The results obtained have been presented and discussed below:

4.1 Biological studies

4.1.1 Egg stage

The eggs were laid in batches of 5 to 6 or singly on the under surface of brinjal leaves or on glass jar or on muslin cloth or on filter paper. Freshly laid eggs were oval in shape and creamy white in colour and measured 0.17 mm in length and 0.10 mm in width (Table 3). When the egg of this pest was about to hatch, it turned into deep orange color with prominent black spot at the tip of the egg which was the developing head of the larva (Plate 2). The present results were in contrast with the findings of Varma and Anandhi (2009) who reported that the mean length varied from 0.56 to 0.63 mm and mean width varied from 0.34 to 0.45 mm.

4.1.2 Incubation period

The mean incubation period was observed during three different months viz. June, August and October. It was found to vary from 3.19 to 5.72 days (Table 1). The minimum incubation period was observed during August (3.19 days) which was statistically at par with June (3.22 days) and differed significantly from October (5.72 days). The results were in accordance with the observations of Varma and Anandhi (2009) who reported the mean incubation period of 4.00 days on brinjal. On garden pea the incubation period of 5.93 days was reported by Onekutu *et al* (2013).

Table 1: Incubation period of brinjal shoot and fruit borer, *L. orbonalis* on brinjal during different months

Months	Incubation period Mean* (days)	Temp. (ºC)	RH (%)
June	3.22 (2.05)	31.45	59.00
August	3.19 (2.04)	29.65	79.25
October	5.72 (2.59)	25.33	65.88
CD (p=0.05)	(0.18)	----	----

*figures in parentheses are $\sqrt{n+1}$ transformed values

Freshly laid

Before hatching

Plate 2: Eggs of brinjal shoot and fruit borer, *L. orbonalis*

4.1.3 Larval stage

The larvae moulted four times and passed through five instars (Plate 3). The larval instars were determined by the number of moults manifested by exuviae formed during moulting. The newly hatched larva was creamy white in colour. The full grown larva was cylindrical and pinkish in colour. The head of the larva was dark brown and had strong mandibles for mastication. The thorax of larva showed three distinct segments with a pair of well developed thoracic legs on each segment. The abdomen had ten segments and five pairs of prolegs.

4.1.3.1 First instar

The young larvae were creamish in color. The mean duration of first instar larvae ranged from 2.53 to 4.08 days. The minimum duration was observed during August (2.53 days) followed by June (3.53 days) and October (4.08 days) (Table 2). The mean duration during three months varied significantly from each other. The first instar larvae fed on the pollen of brinjal flowers. The mean length of first instar was 1.94 mm, width 0.50 mm and head width was observed to be 0.33 mm (Table 3). In contrast to the present findings, Varma and Anandhi (2009) reported duration of 1.40 days with mean length of 1.21 mm, width 0.27 mm and head width of 0.20 mm.

Table 2: Larval duration of brinjal shoot and fruit borer, *L. orbonalis* on brinjal during different months

Months	Mean duration* of different larval instars (days)						Temp (ºC)	RH (%)
	1st	2nd	3rd	4th	5th	Larval period		
June	3.53 (2.12)	3.47 (2.11)	5.27 (2.50)	3.69 (2.16)	3.80 (2.19)	19.78 (4.55)	31.45	59.00
August	2.53 (1.87)	2.11 (1.76)	3.11 (2.02)	2.00 (1.73)	1.56 (1.59)	11.31 (3.50)	29.65	79.25
October	4.08 (2.25)	3.61 (2.14)	5.83 (2.61)	3.58 (2.14)	3.61 (2.14)	20.72 (4.66)	25.33	65.88
CD (p=0.05)	(0.20)	(0.13)	(0.10)	(0.11)	(0.19)	(0.22)	----	----

* Figures in parentheses are $\sqrt{n+1}$ transformed values

4.1.3.2 Second instar

After moulting, the second instar larvae immediately fed on fresh brinjal slices and as it matured, it produced regular holes in the brinjal slices filled with exuviae. The larva stopped feeding a few minutes before moulting. The mean duration of second instar larvae varied from 2.11 to 3.61 days during three different months. The minimum duration was observed during August (2.11 days) followed by June (3.47 days) and October (3.61 days) (Table 2). The mean duration during three months varied significantly from each other. The mean length of second instar was 4.55 mm, width 0.80 mm and head width was observed to be 0.43 mm (Table 3). This instar was marked by the brownish head which was narrower than prothorax. The results collaborate the findings of Varma and Anandhi (2009) who observed the duration as 2.00 days.

4.1.3.3 Third instar

Third instar larva was 8.48 mm in length and 1.69 mm in width with head width of 0.77 mm (Table 3). Small brown spots appeared on the dorsal and ventral sides of the body, the number on the dorsal side being more and from the center of each spot emerged a fine spine. The mean duration of third instar larvae was 3.11 to 5.83 days. The minimum duration was observed during August (3.11 days) followed by June (5.27 days) and October (5.83 days). The mean duration during three months varied significantly from each other (Table 2). In contrast to the present findings Onekutu *et al* (2013) observed the duration of 1.48 days.

4.1.3.4 Fourth instar

At this stage the fourth instar larva measured 10.05 mm in length and 2.10 mm in width with head width of 1.34 mm (Table 3). The mean duration of fourth instar larvae was 2.00 to 3.69 days. The minimum duration was observed during August (2.00 days) followed by October (3.58 days) and June (3.69 days). The mean duration during three months varied significantly from each other (Table 2). In contrast to the present findings, Saxena (1965) reported duration of 01.00 day with mean larval length and width of 9.30 mm and 1.80 mm, respectively.

4.1.3.5 Fifth instar

During this instar, the larva does not appear to feed so voraciously as during the previous instars. The morphology of the larva was almost the same except that there was proportionate increase in the size of different parts of the body and the pupating behavior was more pronounced at this stage. The duration of fifth instar larvae varied from 1.56 to 3.80 days. The minimum duration was observed during August (1.56 days) followed by October (3.61 days) and June (3.80 days). The mean duration during three months varied significantly

1st instar

2nd instar

3rd instar

4th instar

5th instar

Plate 3: Larval instars of brinjal shoot and fruit borer, *L. orbonalis*

from each other (Table 2). The mean length of fifth instar larva was 13.08 mm and mean width was 2.28 mm with head width of 1.36 mm (Table 3). The fifth instar larvae became sluggish and inactive before pupation. It lost its body pigmentation and started preparing cocoon for pupation.

4.1.3.6 Total larval period

The total larval duration observed varied from 11.31 to 20.72 days (Table 2). The minimum duration was observed during August (11.31 days) followed by June (19.78 days) and October (20.72 days). The mean duration during three months varied significantly from each other. The results showed similarity to the earlier findings of Radhakrishore *et al* (2010) who found it to vary from 16.86 days.

4.1.4 Pupal stage

The pupa was 9.49 mm long and 3.13 mm broad with head width of 1.48 mm (Table 3). The freshly formed pupa was pinkish which changed to dark brown with time, elongate oval in shape, gradually tapering posteriorly with almost straight abdomen; wing margins extended up to the posterior margin of the abdominal segment. Pupation occurred on the glass jars, sand, muslin cloth and inside the rotten fruit. The pupal period was found to vary from 7.11 to 9.69 days (Table 5). The minimum duration was observed during August (7.11 days) which was statistically at par with October (7.53 days) and varied significantly from June (9.69 days). The present results are in line with the findings of Saxena (1965) who found it to vary from 8 to 9 days and Allam *et al* (1982) who observed pupal period to be from 7 to 11 days under laboratory conditions. Male and female was also distinguished at pupal stage on the basis of genital slit. In case of male the distance between last abdominal segment and genital slit was more whereas in case of female the distance between two was less (Plate 1).

4.1.5 Adult stage

The adult moth was of white colour with head and thorax covered with greyish and brown scales. The fore wings were creamish white with reinform large patches of light brown colour over it. In case of hind wing a faint black wavy line was observed close to the apical margin. The wings were slightly fringed at the margins. The female moth was generally larger than the male and had tuft of hair at the tip of abdomen (Plate 4). The mean length of adult male was observed as 7.66 mm and mean width was observed as 17.66 mm across the wings whereas in case of female the mean length was observed as 10.50 mm and mean width was observed as 19.00 mm across the wings (Table 3).

Table 3: Measurements of different developmental stages of brinjal shoot and fruit borer, *L. orbonalis* Guenee

Stage		Length	Width	Head width
		Mean±SD (mm)		
Egg*		0.17 ± 0.06	0.10 ± 0.05	
Larval stages**	1st instar	1.94 ± 0.02	0.50 ± 0.09	0.33 ± 0.02
	2nd Instar	4.55 ± 0.56	0.80 ± 0.21	0.43 ± 0.05
	3rd Instar	8.48 ± 0.36	1.69 ± 0.14	0.77 ± 0.06
	4th Instar	10.05 ± 0.43	2.10 ± 0.25	1.34 ± 0.08
	5th instar	13.08 ± 0.00	2.28 ± 0.06	1.36 ± 0.08
Pupa**		9.49 ± 0.09	3.13 ± 0.05	1.48 ± 0.57
Adult	Male	7.66 ± 0.58	17.66 ± 0.58	
	Female	10.50 ± 0.71	19.00 ± 1.14	

* Observations at 80 X magnification
** Observations at 10 X magnification

4.1.6 Oviposition period

The oviposition period was observed to vary from 1.54 to 2.40 days (Table 4). The maximum duration was observed during August (2.40 days) followed by June (1.90 days) and October (1.54 days). The mean duration during three months varied significantly from each other. The results were almost similar to the observations of Jat *et al* (2003) who observed the oviposition period of 2.43 days.

4.1.7 Fecundity

The fecundity of *L. orbonalis* was observed to vary from 38.20 to 74.60 during three different months (Table 4). The maximum egg laying was observed during August i.e. 74.60 eggs followed by 42.60 eggs during June and 38.20 eggs during October. The fecundity during three months varied significantly from each other. In contrast to the present findings, Singh and Singh (2001a) reported average egg laying of 174.95 eggs per female.

Table 4: Oviposition period and fecundity of brinjal shoot and fruit borer, *L. orbonalis* on brinjal during different months

Months	Oviposition period*	Fecundity*	Temp. (ºC)	RH(%)
June	1.90 (1.70)	42.60 (6.56)	31.45	59.00
August	2.40 (1.84)	74.60 (8.66)	29.65	79.25
October	1.54 (1.59)	38.20 (6.12)	25.33	65.88
CD (p=0.05)	(0.14)	(1.45)	----	----

* Figures in parentheses are $\sqrt{n+1}$ transformed values

Male

Female

Plate 4: Male and female moth of brinjal shoot and fruit borer, *L. orbonalis*

4.1.8 Longevity of adults

In general, females lived longer than males. Mean longevity of adults was observed to be 1.83 to 2.00 days whereas in case of female, the longevity varied from 3.66 to 4.16 days (Table 5). The results are in accordance with Jat *et al* (2003) who observed male longevity as 1.82 days and female longevity as 3.12 days, while these differ from the observations of Kavitha *et al* (2008) who observed male longevity as 3.50 days and female longevity as 5.70 days.

Table 5: Pupal period and adult longevity of brinjal shoot and fruit borer, *L. orbonalis* on brinjal during different months

Months	Mean* (days)			Temp. (ºC)	RH (%)
	Pupal period	Adult longevity			
		Female	Male		
June	9.69 (3.26)	3.66	1.83	31.45	59.00
August	7.11 (2.84)	4.16	2.00	29.65	79.25
October	7.53 (2.91)	3.66	2.00	25.33	65.88
CD (p=0.05)	(0.10)	NS	NS	----	----

* Figures in parentheses are $\sqrt{n+1}$ transformed values

4.1.9 Total life span

The total life span was observed to vary from 25.06 to 36.72 days (Table 6). The minimum duration was observed during August (25.06 days) followed by June (35.61 days) and October (36.72 days) (Fig. 1). The mean duration during three months varied significantly from each other. The present findings are in accordance with Singh and Singh (2001a) who reported life cycle of 36.82 days.

Table 6: Total life span of brinjal shoot and fruit borer, *L. orbonalis* on brinjal during different months

Months	Total life span*	Temp. (ºC)	RH(%)
June	35.61 (6.05)	31.45	59.00
August	25.06 (5.10)	29.65	79.25
October	36.72 (6.14)	25.33	65.88
CD (p=0.05)	(0.17)	----	----

* Figures in parentheses are $\sqrt{n+1}$ transformed values

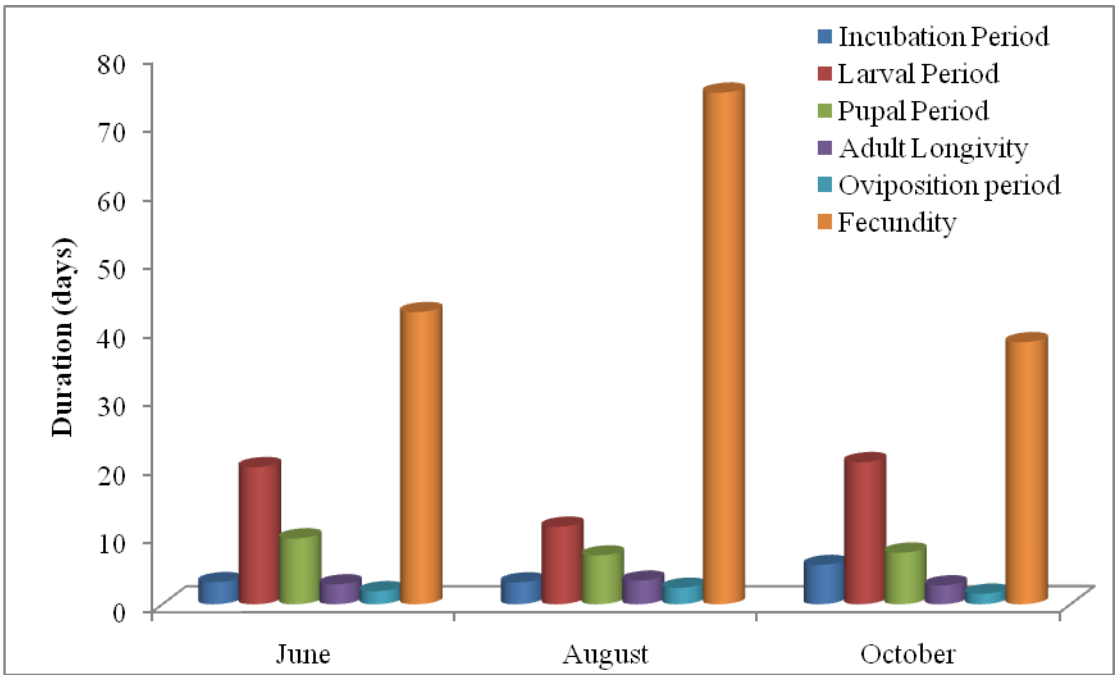


Fig. 1: Total life span of brinjal shoot and fruit borer, *L. orbonalis* during different months

4.1.10 Sex ratio

Sex ratio (female: male) was observed to be varying from 1.16:1 to 2.00:1 days (Table 7). Females outnumbered males and the results are in accordance with Patil *et al* (2007) who observed sex ratio of female: male as 1.3:1 however, Taley *et al* (1984) observed sex ratio of 2:1.

Table 7: Sex ratio of brinjal shoot and fruit borer, *L. orbonalis*, on brinjal during different months

Months	Sex ratio (female: male)	Temp. (ºC)	RH (%)
June	2.00:1	31.45	59.00
August	1.16:1	29.65	79.25
October	1.40:1	25.33	65.88

4.2 Seasonal incidence of brinjal shoot and fruit borer, *L. orbonalis*, on brinjal

To study the seasonal incidence of BSFB in different months three successive crops of brinjal were grown at Entomological Research Farm, Punjab Agricultural University, Ludhiana.

4.2.1 Shoot infestation

For determining the incidence of *L. orbonalis*, the shoots were carefully examined at weekly intervals. Peak shoot infestation was observed during 31st standard week (SW) (9.11)

as with the increase in rain fall there was increase in shoot infestation. Also during November-December (44th to 52nd SW) when there was comparatively less rainfall and decrease in temperature, damage caused by BSFB on shoots was present but the intensity was low (0.22-1.22). During April-May (14th to 18th SW) when the temperature started rising the shoot infestation was present on brinjal plants but intensity of damage was low (0.56-0.78). The correlation coefficients between the mean number of shoots infested and the climatic factors i.e. maximum and minimum temperature, relative humidity, rainfall and sunshine hours was worked out for the period May 2011- May 2012. The BSFB population showed a significant positive correlation with the maximum and minimum temperature, relative humidity and rainfall where as it showed a negative correlation with sunshine hours (Table 8). In contrast to present findings Meena *et al* (2012) reported peak period of shoot infestation in 9th SW (5.4 per cent) and 7th SW (4.6 per cent) followed by 8th SW (4.5 per cent).

Table 8: Seasonal incidence of brinjal shoot and fruit borer, *L. orbonalis* Guenee, on brinjal shoots during 2011-2012

Meterological Standard Week (SW)	Max. Temp. (°C)	Min. Temp. (°C)	RH (%)	Rainfall (mm)	Sunshine (hrs)	Mean no. of infested shoots
20	43.00	26.80	31.00	00.00	07.80	0.00
21	39.40	27.00	54.00	09.40	11.30	0.00
22	40.00	26.80	45.00	01.20	08.90	0.00
23	41.00	29.00	57.00	00.00	10.40	0.00
24	30.00	26.00	54.00	02.10	08.70	0.00
25	33.00	25.80	80.00	02.20	06.30	0.00
26	31.40	23.20	89.00	00.00	05.70	0.78
27	33.20	26.00	80.00	08.80	04.70	3.11
28	34.40	26.40	79.00	00.00	10.00	4.33
29	34.20	25.00	77.00	30.00	01.30	6.22
30	35.40	27.60	83.00	00.80	00.00	8.33
31	36.20	26.20	77.00	02.50	10.50	9.11
32	34.00	25.60	73.00	00.00	06.70	3.44
33	32.60	24.20	85.00	00.00	09.90	2.33
34	33.40	25.00	82.00	02.40	04.70	2.11
35	33.80	26.20	87.00	01.00	04.60	0.00
36	27.60	23.80	96.00	25.80	00.00	0.00
37	29.00	24.20	91.00	44.60	01.90	0.00
38	32.80	23.40	75.00	00.00	10.00	0.00
39	32.60	21.80	73.00	00.00	10.20	0.00
40	33.00	22.40	69.00	00.00	10.50	0.00
41	34.00	19.40	72.50	00.00	09.30	0.00

Meterological Standard Week (SW)	Max. Temp. (^{o}C)	Min. Temp. (^{o}C)	RH (%)	Rainfall (mm)	Sunshine (hrs)	Mean no. of infested shoots
42	32.40	15.60	60.00	00.00	09.10	0.00
43	30.80	15.00	62.00	00.00	08.20	0.00
44	30.00	31.60	67.00	00.00	05.20	0.22
45	28.20	13.50	67.00	00.00	09.40	0.33
46	28.40	12.50	70.00	00.00	09.10	0.45
47	27.60	12.60	73.00	00.00	00.00	1.22
48	26.20	12.60	72.00	00.00	08.50	1.11
49	26.50	10.00	75.00	00.00	08.50	1.11
50	26.40	06.60	76.00	00.00	08.20	1.13
51	21.20	06.00	79.00	00.00	06.70	1.22
52	19.00	02.20	79.00	00.00	05.90	0.33
2012						
1	22.60	04.60	66.00	00.00	06.80	0.56
2	16.40	04.40	81.00	00.00	08.20	0.00
3	14.10	05.40	85.00	00.00	08.50	0.00
4	14.20	05.80	89.00	00.00	00.00	0.00
5	18.20	04.20	68.00	00.00	09.60	0.00
6	19.60	06.80	66.00	00.00	07.20	0.00
7	18.20	02.00	65.00	00.00	10.00	0.00
8	18.00	01.70	72.00	00.00	10.30	0.00
9	20.80	08.40	65.00	00.00	05.70	0.00
10	25.40	10.00	63.00	00.00	09.80	0.00
11	23.60	07.40	69.00	00.00	10.90	0.00
12	30.00	12.20	63.00	00.00	08.80	0.00
13	33.00	13.60	63.00	00.00	10.60	0.00
14	34.40	18.20	44.00	00.00	08.50	0.56
15	32.00	14.20	59.00	00.00	11.40	0.78
16	33.00	19.50	53.00	00.00	08.50	0.78
17	35.00	20.00	54.00	00.00	08.20	0.78
18	36.60	25.00	30.00	00.00	05.00	0.78
Coefficient of correlation (r)	0.284*	0.343*	0.245	0.142	-0.248	

'r' value at n-2 d.f. at 5% = 0.273

Regression equation for average shoot infestation :

$Y= - 6.573X_1 + 0.168X_2 - 0.027X_3 + 0.06X_4 - 0.028X_5 - 0.133X_6$

R^2 (Coeff. of determination) = 0.2638

Multiple R-value = 0.5137

The coefficient of determination (R^2) was calculated to measure the contribution of linear function of independent variables i.e maximum temperature (X_1), minimum temperature (X_2), relative humidity (X_3), rainfall (X_4) and sunshine hours (X_5) on dependent variables i.e mean shoot infestation. The multiple regression equation was also calculated and is given below:

$Y = - 6.573X_1 + 0.168X_2 - 0.027X_3 + 0.06X_4 - 0.028X_5 - 0.133X_6$

R^2 (Coeff. of determination) = 0.2638

It can be concluded that whenever there is increase in rainfall and relative humidity with decreasing temperature during July-August, the incidence of BSFB on shoots of brinjal plant is expected to increase.

4.2.2 Fruit infestation

For determining the incidence of *L. orbonalis*, on brinjal fruits, the fruits were examined at weekly intervals. Peak fruit infestation was observed during 32nd SW (2.56) as with the increase in rainfall there was increase in fruit infestation. Also during November-December (44th to 52nd SW) when there was comparatively less rainfall and decrease in temperature, damage caused by BSFB on brinjal fruits was present but the intensity was low (0.11-0.56). The correlation coefficients between the mean fruit infestation and the climatic factors i.e. maximum and minimum temperature, relative humidity, rainfall and sunshine hours was worked out for the period May 2011- May 2012. BSFB population showed a positive correlation with all the abiotic factors i.e. maximum and minimum temperature, relative humidity, rainfall and sunshine hrs. But it showed a significant positive correlation with minimum temperature and relative humidity (Table 9). In contrast to present findings Ghosh and Senapati (2009) reported peak infestation (81.0 per cent fruit damage) during 22nd SW, while Meena *et al* (2012) reported peak infestation of fruit borer during 18th SW (43.3 per cent) and 17th SW (40.1 per cent).

The coefficient of determination (R^2) was calculated to measure the contribution of linear function of independent variables i.e maximum temperature (X_1), minimum temperature (X_2), relative humidity (X_3), rainfall (X_4) and sunshine hours (X_5) on dependent variables i.e mean fruit infestation. The multiple regression equation was also calculated:

$Y = - 2.448X_1 + 0.042X_2 + 0.003X_3 + 0.025X_4 - 0.023X_5 - 0.03X_6$

R^2 (Coeff. of determination) = 0.3103

It can be concluded that whenever there is increase in rainfall and relative humidity with decreasing temperature during July-August, the incidence of BSFB on fruits of brinjal plant is expected to increase.

Table 9: Seasonal incidence of brinjal shoot and fruit borer, *L. orbonalis* Guenee, on brinjal fruits during 2011-2012

Meterological Standard Week (SW)	Max. Temp. (^{o}C)	Min. Temp. (^{o}C)	RH (%)	Rainfall (mm)	Sunshine (hrs)	Mean no. of infested fruits
20	43.00	26.80	31.00	00.00	07.80	0.00
21	39.40	27.00	54.00	09.40	11.30	0.00
22	40.00	26.8	45.00	01.20	08.90	0.00
23	41.00	29.00	57.00	00.00	10.40	0.00
24	30.00	26.00	54.00	02.10	08.70	0.00
25	33.00	25.80	80.00	02.20	06.30	0.00
26	31.40	23.20	89.00	00.00	05.70	0.11
27	33.20	26.00	80.00	08.80	04.70	0.67
28	34.40	26.40	79.00	00.00	10.00	0.67
29	34.20	25.00	77.00	30.00	01.30	0.89
30	35.40	27.60	83.00	00.80	00.00	2.00
31	36.20	26.20	77.00	02.50	10.50	2.00
32	34.00	25.60	73.00	00.00	06.70	2.56
33	32.60	24.20	85.00	00.00	09.90	2.44
34	33.40	25.00	82.00	02.40	04.70	1.89
35	33.80	26.20	87.00	01.00	04.60	0.00
36	27.60	23.80	96.00	25.80	00.00	0.00
37	29.00	24.20	91.00	44.60	01.90	0.00
38	32.80	23.40	75.00	00.00	10.00	0.00
39	32.60	21.80	73.00	00.00	10.20	0.00
40	33.00	22.40	69.00	00.00	10.50	0.00
41	34.00	19.40	72.50	00.00	09.30	0.00
42	32.40	15.60	60.00	00.00	09.10	0.00
43	30.80	15.00	62.00	00.00	08.20	0.00
44	30.00	31.60	67.00	00.00	05.20	0.11
45	28.20	13.50	67.00	00.00	09.40	0.11
46	28.40	12.50	70.00	00.00	09.10	0.11
47	27.60	12.60	73.00	00.00	00.00	0.56

Meterological Standard Week (SW)	Max. Temp. (^{o}C)	Min. Temp. (^{o}C)	RH (%)	Rainfall (mm)	Sunshine (hrs)	Mean no. of infested fruits
48	26.20	12.60	72.00	00.00	08.50	0.54
49	26.50	10.00	75.00	00.00	08.50	0.33
50	26.40	06.60	76.00	00.00	08.20	0.36
51	21.20	06.00	79.00	00.00	06.70	0.44
52	19.00	02.20	79.00	00.00	05.90	0.33
2012						
1	22.60	04.60	66.00	00.00	06.80	0.00
2	16.40	04.40	81.00	00.00	08.20	0.00
3	14.10	05.40	85.00	00.00	08.50	0.00
4	14.20	05.80	89.00	00.00	00.00	0.00
5	18.20	04.20	68.00	00.00	09.60	0.00
6	19.60	06.80	66.00	00.00	07.20	0.00
7	18.20	02.00	65.00	00.00	10.00	0.00
8	18.00	01.70	72.00	00.00	10.30	0.00
9	20.80	08.40	65.00	00.00	05.70	0.00
10	25.40	10.00	63.00	00.00	09.80	0.00
11	23.60	07.40	69.00	00.00	10.90	0.00
12	30.00	12.20	63.00	00.00	08.80	0.00
13	33.00	13.60	63.00	00.00	10.60	0.00
14	34.40	18.20	44.00	00.00	08.50	0.00
15	32.00	14.20	59.00	00.00	11.40	0.00
16	33.00	19.50	53.00	00.00	08.50	0.00
17	35.00	20.00	54.00	00.00	08.20	0.00
18	36.60	25.00	30.00	00.00	05.00	0.00
Coefficient of correlation (r)	0.225	0.314*	0.321*	0.009	-0.188	

'r' value at n-2 d.f. at 5% = 0.273

Regression equation for average fruit infestation:

$Y= - 2.448X_1 +0.042X_2 + 0.003X_3 + 0.025X_4 – 0.023X_5 – 0.03X_6$

R^2 (Coeff. of determination) = 0.3103

Multiple R-value = 0.5571

4.2.3 Nature of damage

In early vegetative stage of the crop, the larva bored into the tender shoots resulting in withering and drying of the affected shoots. During the reproductive stage, the larva bored into the flower buds and fruits and plugged the bored holes with excreta (Plate 5). It was found to feed by making tunnels in the brinjal fruits, which showed that it is an internal feeder. Further, the first and second instar larvae were found in the receptacle of the flower buds and flowers whereas third and fourth instar larvae were found in the shoots and fruits. The fifth instar larvae were found only in mature fruits. The present findings are in line with the findings of Sandanayake and Edirisinghe (1992) who studied the larval distribution of BSFB on brinjal flowers, shoots and fruits.

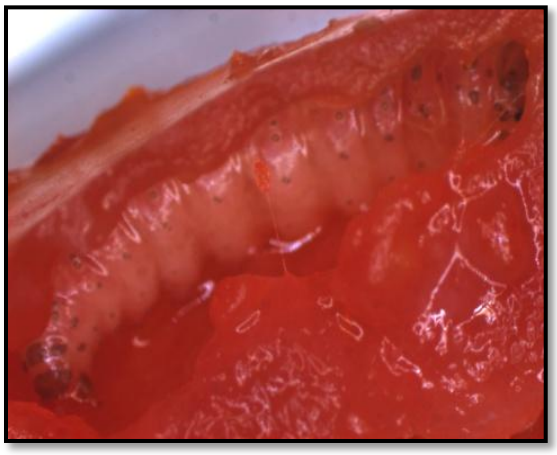
4.3 Alternate hosts of *L. orbonalis*

To observe the survival of BSFB on various alternate host plants, seeds of some weeds and crops were procured and were planted in pots at Entomological Research Farm, Punjab Agricultural University, Ludhiana. Observations were recorded at ten days interval to observe the feeding and survival of this pest over various plants. The BSFB larvae were observed to feed on *S. nigrum, P. minima, L. esculentum* and *S. tuberosum*, all belonging to family Solanaceae whereas it was not observed to feed on *A. aspera* belonging to family Amaranthaceae (Plate 6). On *S. nigrum* and *P. minima* it was reported to cause damage to berries. On *L. esculentum and S. tuberosum* it was reported to cause damage similar to brinjal plant. The above findings are in accordance with Ardez *et al* (2008) and Shukla and Khatri (2010) who reported *L. esculentum, A. esculentus, S. tuberosum, S. nigrum, Cynodon indicum, Oscimum basilicum* and *S. indicum* as the alternate hosts of this pest.

Shoot damage

Fruit damage

Plate 5: Damage caused by brinjal shoot and fruit borer, *L. orbonalis*



Lycopersicon esculentum

Physalis minima

Solanum tuberosum

Solanum nigrum

Plate 6: Alternate hosts of brinjal shoot and fruit borer, *L. orbonalis*

CHAPTER V

SUMMARY

Brinjal (*Solanum melongena* L.) belonging to family Solanaceae is a popular and economically important vegetable crop among small-scale farmers and low-income consumers of South Asia. In India, it occupies an area of 704.96 thousand hectares with an annual production of 12994.77 thousand metric tonnes while in Punjab, it is grown over an area of 3.38 thousand hectares with an annual production of 72.00 thousand metric tonnes. Although it is a summer crop, it is being grown throughout the year under irrigated conditions and is attacked by number of insect and mite pests right from nursery stage till harvesting. Among various insect pests brinjal shoot and fruit borer (BSFB) is the key pest attacking brinjal.

The yield loss due to BSFB has been estimated up to 95 per cent in India. The studies on the biology of this pest were studied in many states of India but were lacking under Punjab conditions. Thus, taking into account the emerging problem of BSFB, *Leucinodes orbonalis,* on brinjal in Punjab, the detailed studies on "Biology and seasonal incidence of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee" were conducted at Entomological Research Farm and the Acarology laboratory of the Department of Entomology, Punjab Agricultural University, Ludhiana during 2011-2012.

Various biological parameters of *L. orbonalis* were studied at room temperature under laboratory conditions. Observations were recorded daily for incubation period, larval period, pupal period, oviposition period, adult longevity, fecundity and sex ratio. Biometric measurements of different developmental stages of BSFB were also recorded. Data on seasonal incidence of BSFB under field conditions and its survival over various alternate hosts were also recorded. For recording the data on seasonal incidence, ten plants were selected at random from each replication for observing the shoot and fruit infestation. All the above ground plant parts were observed keenly to observe the infestation and nature of damage caused by this pest.

The mean incubation period was observed during three different months viz. June, August and October. It was found to vary from 3.19 to 5.72 days with minimum duration during August (3.19 days) which was statistically at par with June (3.22 days) and differed significantly from October (5.72 days).

During larval development, the larvae moulted four times and thus passed through five instars. There were significant differences in duration of different instars during three different months. The total larval duration observed varied from 11.31 to 20.72 days. The minimum duration was observed during August (11.31 days) followed by June (19.78 days)

and October (20.72 days). The mean duration during three months varied significantly from each other.

The freshly formed pupa was pinkish in colour and was 9.49 mm long and 3.13 mm broad with head width of 1.48 mm. The pupal period was found to vary from 7.11 to 9.69 days. The minimum duration was observed during August (7.11 days) which was statistically at par with October (7.53 days) and varied significantly from June (9.69 days). The male and female were also distinguished at pupal stage on the basis of genital slit.

The oviposition period was observed to vary from 1.54 to 2.40 days. The maximum duration was observed during August (2.40 days) followed by June (1.90 days) and October (1.54 days). The mean duration during three months varied significantly from each other.

In general, the females lived longer than males. Mean longevity of males was observed to vary from 1.83 to 2.00 days while in case of females, it varied from 3.66 to 4.16 days. Females outnumbered the males and the sex ratio (female: male) was observed to vary from 1.16:1 to 2.00:1 days. Fecundity of *L. orbonalis* was observed to vary from 38.20 to 74.60 during three different months. The maximum egg laying was observed during August i.e. 74.60 eggs followed by 42.60 eggs during June and 38.20 eggs during October.

The total life cycle varied from 25.06 to 36.72 days. The minimum duration was observed during August (25.06 days) followed by June (35.61 days) and October (36.72 days).

Peak shoot infestation was observed during 31st SW (9.11). During April-May (14th to 18th SW) and during November-December (44th to 52nd SW) damage was observed on shoots but the intensity was low. Peak fruit infestation was observed during 32nd SW (2.56).

L. orbonalis was also observed to feed on various other members of Solanaceae family i.e. *S. nigrum* (Black nightshade), *P. minima, L. esculentum* (Tomato) and *S. tuberosum* (Potato) whereas it does not showed feeding preference for *A. aspera* (Family – Amaranthaceae).

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